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AMO research in graphene and 2D material devices for sensing applications and their access through INFRACHIP

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Summary:

The EU-funded INFRACHIP project gives access to advanced technologies and addresses innovation and funding challenges. As an access provider, AMO GmbH offers infrastructure for deposition, etching, lithography and advanced characterization, as well as expertise in the fabrication of graphene and other 2D material-based devices. By integrating 2D materials into electronic and photonic devices with scalable fabrication processes and versatile photonic platforms, AMO supports cutting-edge R&D and delivers tailored solutions for next-generation sensing and electronic applications.

Keywords: Infrastructure, 2D Materials, Sensors, Photonics, Electronics

Introduction

Technology is advancing rapidly, yet ideas often face hurdles due to limited access to state-of-the-art or cutting-edge manufacturing capabilities. Securing funding can also be a lengthy process, if successful at all. EU-sponsored infrastructure projects play a crucial role in maintaining high standards of science and research within Europe. The INFRACHIP project addresses these challenges by offering a streamlined proposal process and quick access to relevant technologies. This initiative is supported by funding from the European Union's Horizon Europe research and innovation program under Grant Agreement No. 101131822.

AMO GmbH is a non-profit SME specializing in R&D for micro- and optoelectronic applications and one of the 11 service providers involved in the INFRACHIP initiative. The technology portfolio offered by AMO includes not only different deposition, etching, and lithography tools but also advanced characterization techniques and the fabrication of graphene and other 2D Materials devices for sensor applications. [1] What characterizes AMO as a service provider is flexibility, a short feedback loop with customers, and a broad range of solutions based on the know-how and technologies developed in our research projects.

Sensors and Detectors based on 2D Materials

Graphene and other two-dimensional materials appeared on the stage first in 2004, raising great expectations that they could revolutionize microelectronics [2]. These expectations were largely driven by the excellent intrinsic properties of graphene: high carrier mobility, broadband optical absorption, ultimate thinness, and high mechanical strength.

At AMO, research on graphene and other 2D materials has been ongoing since 2006, with a particular focus on their potential applications in microelectronics and optoelectronics. Of particular interest is the integration of 2D materials with conventional silicon technology to develop new applications in electronics, sensing and photonics.

Graphene-based field-effect transistors for sensing applications

Several advanced devices based on 2D materials have been demonstrated in various publications, including Hall sensors [3, 4], pressure sensors [5, 6], photodetectors [7, 8], and diodes [9]. In addition, recent advancements have achieved low contact resistivity in graphene field-effect transistors (GFETs) [10, 11] and MoS_2 Transistors [12], a critical factor since high contact resistance can severely limit device performance, scalability, and energy efficiency.

An example of graphene-based Hall sensors fabricated on a flexible substrate is shown in Fig. 1. These Hall sensors are created on a 50 µm thick flexible Kapton foil using large-scale graphene grown via the chemical vapor deposition technique on copper foil. The devices exhibit voltage and current normalized sensitivities of up to 0.096 V VT^{-1} and 79 V AT^{-1}, respectively – values comparable to those of rigid silicon-based Hall sensors. The performance can be further improved by adding a top gate. In this case, the normalized sensitivities can reach up to 0.68 V VT^{-1} and 2580 V AT^{-1} [4]. Notably, the sensors maintain their sensitivity even after being bent to a minimum radius of 4 mm, corresponding to a tensile strain of 0.6%, and after enduring 1000 bending cycles to a radius of 5 mm.

Our capabilities span both chip-scale fabrication and wafer-scale production, highlighting our commitment to bridging the gap between innovative research and scalable manufacturing. As part of the 2D-EPL and 2D-PL projects [13], we have developed a reliable baseline process for fabricating GFETs on 6" silicon wafers. These GFETs are offered through multi-project wafer (MPW) runs [14], making 2D material-based devices accessible to a broader research and development community. As part of INFRACHIP, AMO offers this expertise to provide users with comprehensive support to drive their R&D initiatives forward.

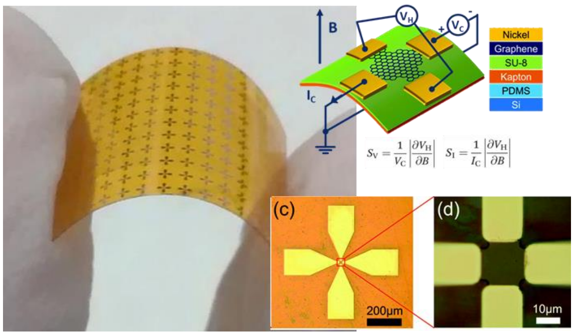

Fig. 1. Flexible Graphene Hall Sensor [3] fabricated at AMO.

Photonic Sensing

AMO's established photonic platforms are built on advanced Silicon-On-Insulator (SOI) technology, available in 220 nm and 400 nm thicknesses, as well as Silicon Nitride (Si_3N_4) layers up to 400 nm thick. This versatile platform enables the fabrication of both passive and active photonic devices, with the added capability of integrating 2D materials for enhanced functionality like photodetectors. Our offerings are summarized in [15].

We are also establishing aluminum nitride (AlN) and alumina (Al_2O_3) as new dielectric waveguide platforms with enhanced transparency in the blue/UV spectrum compared to Si_3N_4. AMO has recently published record low AlN waveguide loss of 0.13 dB/cm in the data communication spectrum [16]. Furthermore, we have achieved <0.7 dB/cm waveguide loss at 405 nm wavelength with Al_2O_3 waveguides, which was also a record at the time of publication [17].

For sensing applications, the integration of 2D materials into photonic devices in any of these platforms unlocks exciting possibilities beyond photodetection [18, 19], like using the 2D material as mid-infrared light emitter [20], as transparent microheater [21] or to build optical modulators for data communication [22]. By combining established photonic technologies with the unique properties of 2D materials, AMO supports the development of next-generation photonic sensing solutions.

Finally, we are combining dielectric waveguides with plasmonics to create biosensors with minimal footprint, setting a record in bulk refractive index sensing sensitivity for this type of detector by reaching 6 µm spectral shift per refractive index unit change in the analyte [23].

Summary

Through INFRACHIP, AMO leverages its expertise to provide comprehensive support for users, enabling them to advance their R&D initiatives. Whether researchers require guidance in prototyping, scaling up to wafer-level manufacturing, or integrating 2D materials into standard semiconductor processes, AMO offers tailored solutions and services to meet their needs. By combining cutting-edge technology, established manufacturing workflows, and customer-centric collaboration, we empower users to unlock the full potential of 2D materials in next-generation electronic and sensing devices.

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